NOVATEC SOLAR

COMPANY, TECHNOLOGY AND PROJECTS

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1 INTRODUCTION TO NOVATEC SOLAR

1.1 COMPANY PROFILE

Novatec Solar was founded in 2006 by engineers with the aim to revolutionise the technology for producing Concentrated Solar Power (CSP) in line with the global shift to renewable energy sources. The company is based in Karlsruhe, Germany with regional offices in Radolfzell (Germany), Spain, Australia and the United States.

Novatec Solar is a leading technology provider and original equipment manufacturer of efficient, low cost direct solar steam generators (solar boilers). The company has developed a patented design for solar boilers using unique linear Fresnel collector technology. Novatec Solar's expert team undertakes manufacture, supply, turnkey delivery and operation of solar boilers for a range of applications including power stations, desalination plants and industrial processes.

Novatec Solar has subjected its innovations to a rigorous due diligence process involving experienced and internationally respected institutes such as the German Aerospace Center (DLR), Fraunhofer Institute for Renewable Energy and the technical service corporation TÜV Süd (Technischer Überwachungsverein Süd). In addition, investors and project stake holders have thoroughly assessed the Novatec Solar technology through independent technical consultants such as Fichtner, Lahmeyer International and Parson Brinckerhoff.

1.2 BUSINESS MODEL

As worldwide fossil fuel supply diminishes, the sun is becoming an increasingly valuable energy supplier. Novatec Solar utilises this cost free source in conjunction with its state-of-the-art technology to offer sustainable energy solutions at competitive prices.

The solar boiler component design has been value engineered to produce low cost solar steam. Novatec Solar establishes highly automated production lines for solar field elements in the vicinity of each project. The company's sustainable delivery approach includes local sourcing of materials as well as local employment for production, construction and operation and maintenance of the plants.

Novatec Solar meets client requirements by reliable, fast, cost effective and quality assured delivery and installation of solar fields.

Novatec Solar's focus areas in the context of the typical work streams in a solar thermal project are outlined in the following diagram:

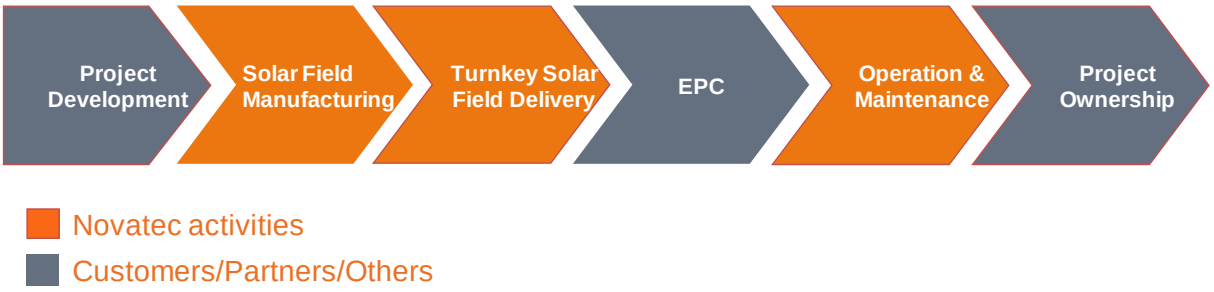

Figure 1 Novatec Solar Activities

1.3 SHAREHOLDER STRUCTURE

The majority shareholder of Novatec Solar is Transfield Holdings, a leading Australian private investment and development company with a record of achievement in engineering infrastructure. In April 2011, ABB AG, the global leader in power and automation technologies, acquired a substantial share in Novatec Solar with the option to assume 100% ownership of the company in 2013. The three founding fathers of Novatec Solar are holding a minority share.

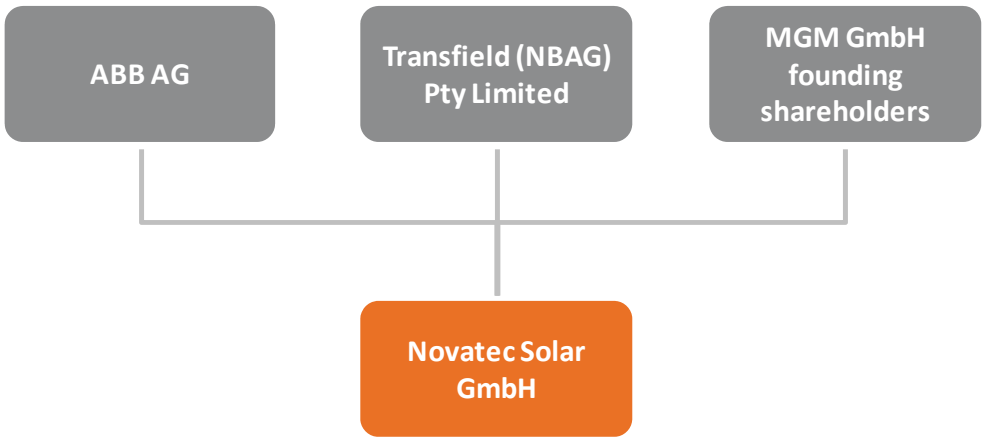

Figure 2 Shareholder Structure Novatec Solar

1.4 MILESTONES

2006		Foundation of Novatec Solar with the aim to revolutionise the technology for producing Concentrating Solar Power.
2007		Novatec's solar field standard module completed and tested.
2008		Commissioning and operation of the first solar field component production line in Spain.
2009		Commissioning of Novatec's first 1.4 MW_{el} solar thermal power plant in Spain.
2010		Start of construction of the 30 MW_{el} power plant PE2 in Spain.
2011		Start of construction of the 9 MW_{th} power plant Liddell in Australia. Augmentation of an existing coal fired plant.
2011		ABB signs an agreement to buy a 35% shareholding in Novatec Solar with the option to acquire 100% in 2013.
2011		First superheated steam generation up to 500°C
2011		Novatec Solar wins SolarPACES Technology Innovation Award 2011

2 NOVATEC SOLAR TECHNOLOGY

Novatec Solar's modular solar boiler is based on the Fresnel collector technology. It is an evolution of parabolic trough technology, using almost flat glass mirrors in place of parabolically curved mirrors. 16 parallel lines of mirrors reflect solar energy onto a receiver in which water is directly vaporized. The resulting steam can be directed to a steam turbine for power generation or used for seawater desalination, solar cooling and other industrial heat applications.

2.1 KEY ATTRIBUTES OF NOVATEC SOLAR'S TECHNOLOGY

The key attributes of Novatec Solar's technology are outlined in the following:

- Direct steam generation:
  - Superheated steam of up to 500 ºC and 100 bars
  - No heat exchangers resulting in higher efficiencies
  - No toxic oil in the absorber tubes
- Proven and bankable technology that passed extensive due diligence processes by independent advisers (Fichtner, Lahmeyer International, Parson Brinckerhoff)
- Scalable solar field size due to modular structure
- Use of standard materials such as sheet plats and glass mirrors
- Automated mass production of key components in locally erected production facility
- State-of-the art assembly process allowing simple, accurate and rapid solar field erection
- High land use efficiency of about 50%
- Minimization of required earth movements as a land slope of 5% can be accommodated
- Low sensitivity to wind loads due to low profile solar field concept
- Low operating cost and water use due to Novatec Solar's robotic cleaning system

2.1 DESCRIPTION OF KEY COMPONENTS

Primary Reflector

The Primary reflector is the most important component of each collector. It is comprised of four flat mirrors pressure glued on to a zinc-coated steel substructure. The sandwich box design of Primary's sub-structure is extremely rigid and provides a secure mounting platform for the mirror segments. The production process aims to ensure each Primary reflector will accurately focus the sun's radiation towards the receiver structure, 7,40 m above mirror level. Novatec Solar's Primary Reflector is robust, durable and suitable for mass production.

Receiver and Secondary Reflector

Solar radiation is focused towards a receiver structure consisting of a Secondary Reflector and an absorber tube. The Secondary Reflector increases the focus target area. Direct focused solar and reflected radiation heats the circulating water / steam mix in the absorber tube at temperatures up to 300°C at pressures of up to 80 bar.
The absorber tube is formed from 70mm diameter high-temperature steel coated with a selective layer to reduce heat losses through thermal emission and maximize thermal absorption.

Tracking motor

The Primary Reflectors in each half of the collector are mechanically coupled and driven as a gang by a small 40W 24V motor. Approximately 256m^2 of mirror are controlled by one motor.
A computer algorithm determines the exact angle of reflection for each Primary Reflector row at each minute of the day at the precise reflector location. Positioning is then further optimised by PV cell readings on either side of the Secondary Reflector allowing fine-tuning commands to be sent to the drive motor as required.

Support structure

The support structure acts as the framework on which the Primary Reflectors are positioned and on which the Receiver is mounted. Novatec Solar's support structure distributes weight effectively and maintains structural rigidity. It uses comparatively small amount of steel. Depending on soil conditions, its lightweight design allows "nail" foundations to be used, saving preparation and assembly time on site.

Cleaning robot

One of the proprietary pieces of equipment designed by Novatec Solar is its cleaning robot. Once placed on the Primary Reflector, the cleaning robot automatically cleans the mirror surface using cleaning brushes and a minimal quantity of water.

2.2 DESCRIPTION OF NOVATEC SOLAR'S TECHNOLOGY

The main components of Novatec's solar boiler are slightly curved glass mirrors (primary reflectors), radiation receivers, foundations, supporting structure and systems that control primary reflector tracking and solar array output.

The basic module consists of 128 primary reflector units with a total mirror surface area of 513.6 m² and 8 receiver units and can be arranged longitudinally to form a collector row. Rows of the following dimensions can be arranged in parallel to form a solar array of any size:

- Minimum row length: 5 modules, 224 m in length
- Maximum row length: 22 modules, 985.6 m in length

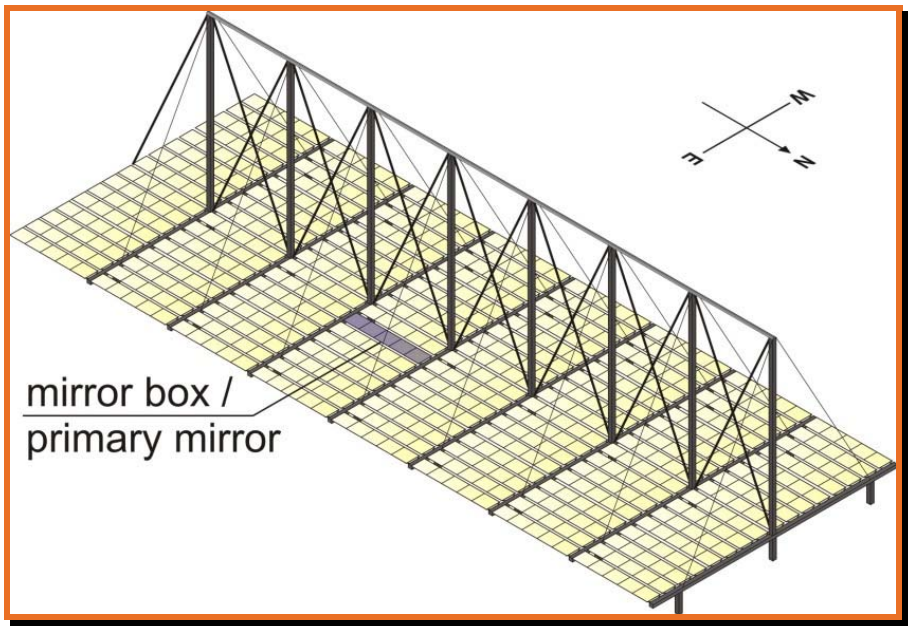

Figure 3 Basic Module

The primary reflectors are installed in parallel rows and focus reflected incident solar radiation onto a focal line.

A receiver is installed along the focal line which consists of a secondary reflector and an absorber pipe. The inclusion of the secondary reflector increases the acceptable target area for the reflected solar radiation from the primary reflector. The absorber pipe absorbs the solar radiation and evaporates water inside the pipe. The receiver structure carries the absorber tube on low friction bearings which accommodate the significant diurnal expansion and contraction of the absorber tube. A flexible connection to the water pipe at the cold end of the row allows the absorber tube to expand and contract. The complete receiver assembly is supported on guyed columns at a height of about 7.40 m above mirror level.

The solar boiler is separated into two sections. The evaporative section works with a water surplus which improves the heat transfer from the absorber pipe to the water and avoids overheating of the absorber pipe. The steam is separated from the water in a water separator with the steam being sent to the superheating section. The resulting superheated steam is utilised in a turbine (or other processes). The water is recirculated to the solar field inlet by circulation pumps. The only difference in design between the evaporative and superheating solar field section is the absorber tube which is vacuum sealed in the superheating part and therefore allows higher temperatures. The steam temperature is controlled at temperature levels of up to 500°C.

During daylight hours the mirror elements are continuously rotated around one axis by servo-motors via gears and a linkage system to maintain the focus of the solar energy on the receiver, regardless of the position of the sun.

Figure 4 Solar Boiler

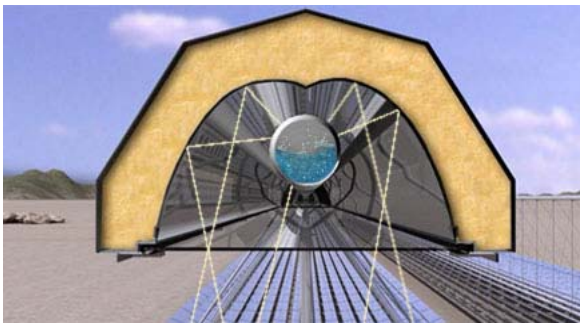

Figure 5 Receiver

As other CSP technologies, Novatec Solar's technology can be coupled with existing storage concepts. Nevertheless, due to the high temperature level of the steam produced by the Novatec system, higher performance can be achieved. The storage technology offering the biggest advantage to the customer will be determined by a detailed project specific evaluation. Possible configurations include short-term steam storage to smoothen fluctuations as applied at PE1 and PE2, and long term storage on the basis of molten salt for load shifting in the evening hours.

3 PERFORMANCE GUARANTEE

Novatec Solar supplies ready-for-use solar steam generators with performance guarantees. The basis for these guarantees is the high precision of industrially produced solar field components and quality controlled solar field assembly. The performance guarantees allow clients to calculate precise steam yields dependent on solar altitude and radiation intensity. This means clients can perform future output planning similar to that of fossil-fuel steam generators.

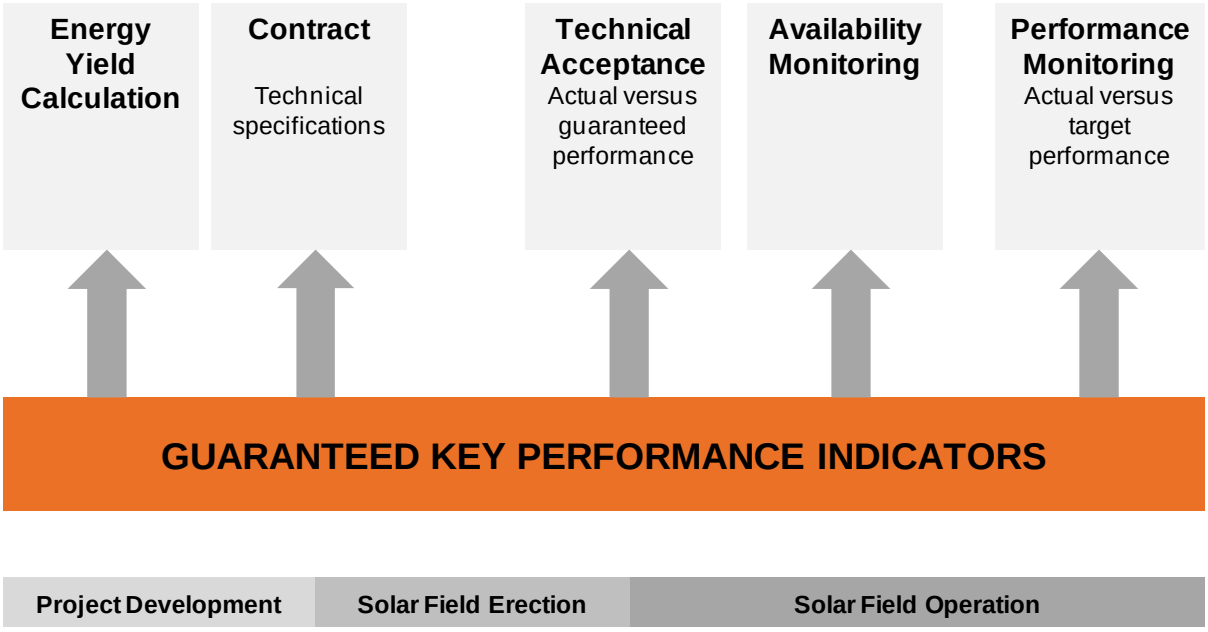

Figure 6 Performance Values

1. The steam yields that have to be attained at the project site, e.g. for power generation, can already be attained in the planning phase with the aid of the guaranteed effectiveness parameters.

2. At execution of the purchase agreement, these same parameters form the guarantee values for the solar boiler to be supplied.

3. Full delivery of the contractual scope of services can be verified by independent auditors at completion of the solar boiler.

4. Novatec Solar makes computer models available that compare the guarantee values calculated based on actual radiation with the actual output values. This continuous software-based examination ensures the long-term efficient operation of the solar boiler.

Novatec Solar warrants the thermal output for any angle position of the sun and the actual DNI. The thermal output of the solar boiler is calculated by multiplying the primary reflector surface with the product of the DNI and the optical efficiency factor minus the heat losses from the receiver radiation (valid for 100% clean primary reflectors and receiver covers). This is also expressed in the following formula:

Pth = A x (DNI x ηopt - Ploss)

whereas:

Pth	=	Solar thermal power output from Solar Boiler in W
A	=	Total surface area of primary reflectors in m2
DNI	=	Direct normal irradiation in W/m2
ηopt	=	Optical efficiency (depending on angle of the sun)
Ploss	=	Heat losses of receiver for 1 m2 of primary reflector surface in W/m2

4 SCOPE OF SERVICES

Novatec Solar provides the following services to its customers:

- Manufacturing of key solar field components using locally established serial production lines
- Solar field assembly and turnkey delivery of solar boilers, including:
  - Provision of expert project management services;
  - Development and provision of all relevant technical documentation;
  - Procurement, supply chain management and logistics;
  - Assembly of the solar boiler; and
  - Testing and commissioning of the solar boiler.
- Solar boiler operation and maintenance services including:
  - Mirror cleaning utilising automated cleaning devices and
  - Performance monitoring.

The Novatec Solar key services are outlined in further detail in the following sections.

Figure 7 Novatec Solar's O+M Services

4.1 SERIAL PRODUCTION OF KEY COMPONENTS

One key advantage of Novatec Solar's technology is the use of standardised components and manufacturing techniques. Novatec Solar has developed a fully-automated production line to assemble primary mirror reflector elements.

Robotic tools used widely in the automotive industry are employed in the production process. Latest state-of-the-art manufacturing technology ensures accuracy and constant, high quality output. The glass mirrors and steel plates used in production are standard, low cost, readily available industrial products.

Logistical and transport advantages are a by-product of establishing manufacturing factories in target market regions close to the solar field. Special transport frames ensure that reflector components are delivered to the assembly site undamaged.

With such production methodology and concept, Novatec Solar

- brings a high technology production process into the target markets;
- reduces transport costs for material deliveries;
- stimulates national and regional economies by utilising local suppliers when possible; and
- creates local employment in its assembly factory.

Figure 8 Serial production

4.2 ASSEMBLY OF SOLAR BOILER

Novatec Solar has redesigned the conventional solar field system assembly process. Simplicity and accuracy are emphasized from initial earth moving stages, through construction of foundations and frameworks, to collector assembly.

Minimal components and simple assembly standards embedded in precise measurement and control procedures have set new quality standards.

Quality control begins with continuous measurement during manufacture and continues through to assembly of solar field components. Concentrating solar boiler energy performance relies on geometrical accuracy. Therefore, all production steps are continually checked in real time against target values. Use of a tachymeter during assembly assures alignment of the supporting structure enabling Novatec Solar to guarantee accurate calculable energy efficiency.

Figure 9 Assembly

4.3 CLEANING SYSTEM

The Novatec Solar reflectors are regularly cleaned to ensure maximum reflection using an automated process with machines designed by Novatec Solar. The system does not use water sprays. Ordinary tap water is used only to moisten the cleaning brushes and water consumption for cleaning is measured in liters per day in comparison to the kiloliters of usually demineralized water used by parabolic trough and other linear Fresnel systems.

Further, Novatec Solar's cleaning system does not require that any part of the solar boiler be taken out of service and while it is possible to undertake cleaning at night. Novatec Solar's cleaning system has been designed to achieve a 97% cleanliness rating (depending on the number of cleaning cycles planned), compared with 92% of conventional parabolic trough fields.

Cleaning performance is 8100 m²/h, and the specific consumption is only approximately 1.1l of water per square meter and year. The number of cleaning cycles is dependent on site specific conditions (dusty area, wind).

Figure 10 Automated 3 trailer cleaning machine

5 FIELDS OF APPLICATION

5.1 ELECTRICITY

Novatec Solar offers a turnkey solar boiler which can be utilised in solar power plants. The boiler can also be easily integrated into hybrid power plants or used to save fuel in conventional power plants.

Solar boiler interfaces:

- Feed water input
- Superheated steam output
- Power supply
- Data control

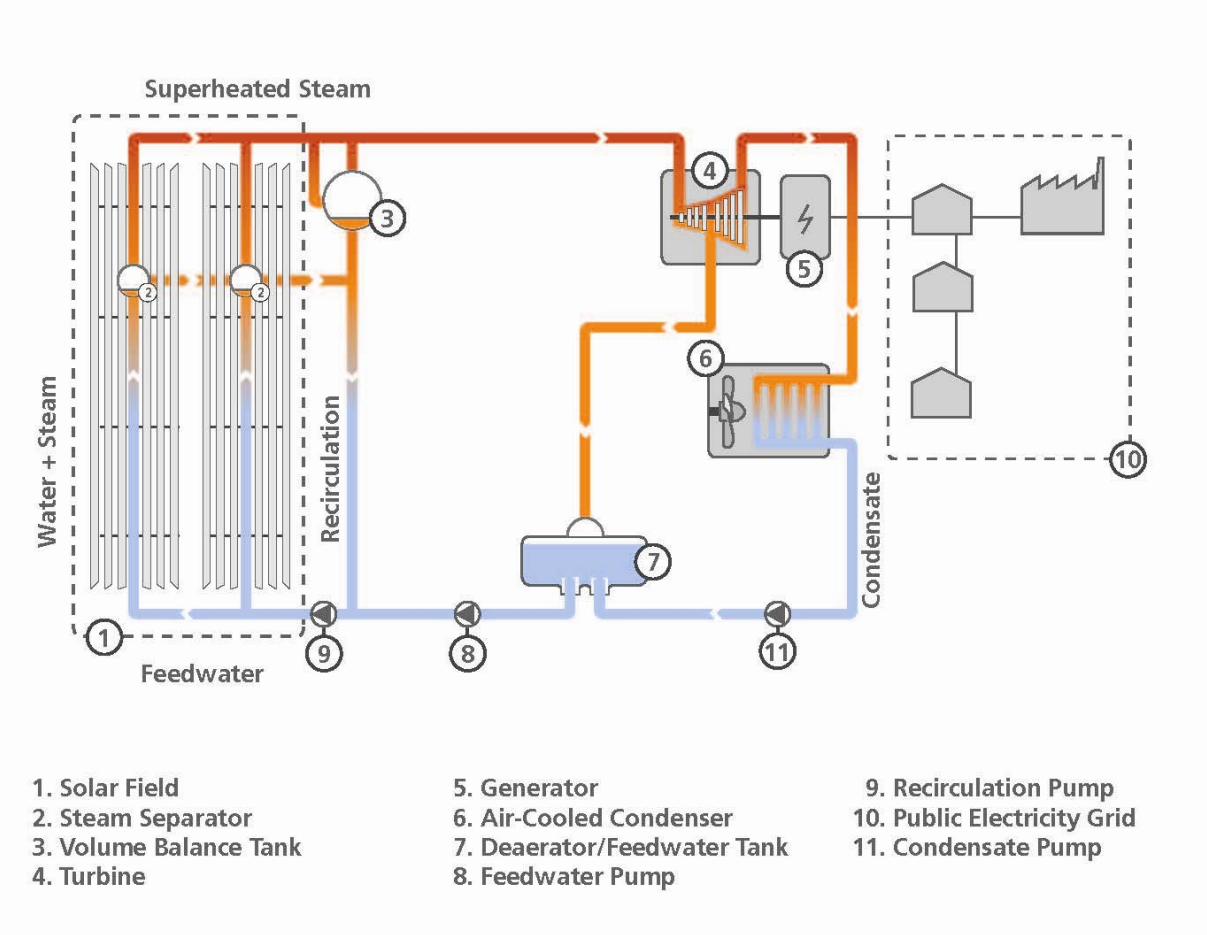

Figure 11 Application CSP Power Station

5.2 SEAWATER DESALINATION

As global demand for fresh water increases, so does the requirement for seawater desalination. Using the sun's energy to desalinate water is a logical step in regions with strong solar irradiation and a high demand for potable water.

Due to its simplified design, Novatec Solar's solar boiler can be easily integrated into seawater desalination plants.

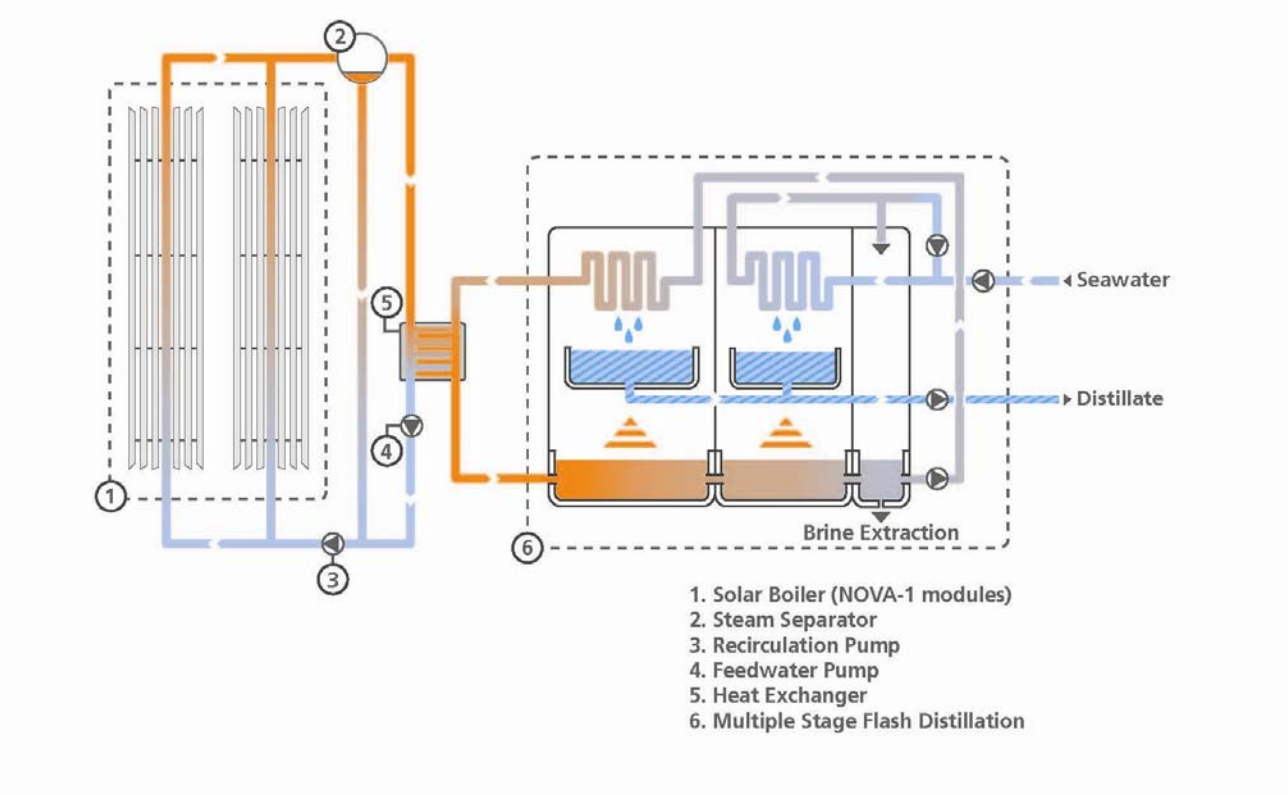

Figure 12 Application Desalination

5.3 COOLING

There is a growing demand for low cost district cooling in areas with high population density. Novatec's solar boiler can meet this demand by using solar-produced steam and absorption chillers. Cooling energy is carried to the consumers in transmission line networks.

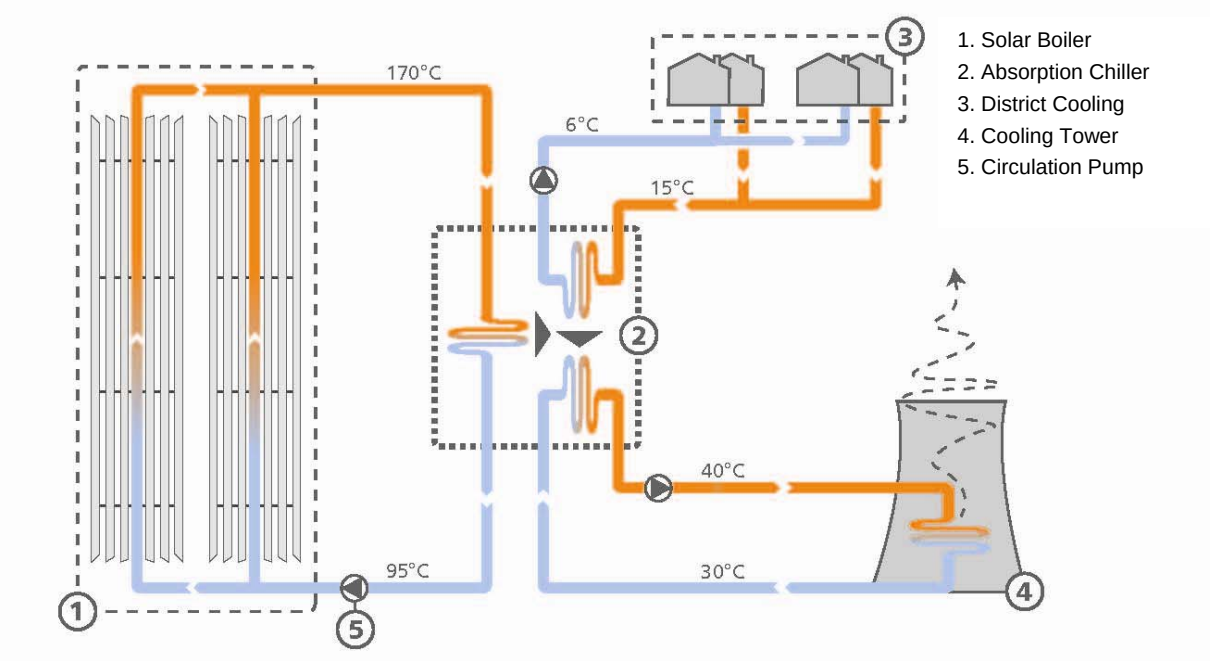

Figure 13 Application Solar Cooling

5.4 PROCESS STEAM

With its simplified design, Novatec Solar Field can be easily integrated into medium temperature industrial applications such as those in the food, textile or chemical industries or for other application using steam as for example enhanced oil recovery.

6 PROJECTS

Novatec Solar's current solar technology projects are shown in the following table.

Project Name	Capacity	Plant Type	Solar Field Size	Status
Puerto Errado 1 (PE1) Murcia, Spain	1.4 MW_e	Demonstration plant	21,571.2 m^2	In commercial operation since March 2009
Puerto Errado 2 (PE2) Murcia, Spain	30 MW_e	Solar thermal power station	302,000 m^2	Construction Start: Apr 2010 Construction End: Mar 2012
Liddell NSW, Australia	9 MW_{th}	Solar augmentation of a coal-fired power station	18,500 m^2	Construction Start: Jan 2011 Construction End: Feb 2012

The first commercial plant build by Novatec Solar was the 1.4 MW_e solar thermal power station 'Puerto Errado 1' (PE 1). The PE1 plant has been in full operation since 10 April 2009 in southern Spain. The power station is currently used to demonstrate Novatec's superheating solar technology and verify the theoretical output values for the steam and power generation.

Next to the PE1 site, Novatec Solar as EPC Contractor is currently constructing the solar thermal power station 'Puerto Errado 2' (PE2). Construction of this utility scaled project with a capacity of 30 MW_e commenced in April 2010 and is scheduled to be synchronised by March 2012. The project will be registered under the Spanish feed-in tariff regime. The PE2 project is owned by five Swiss utilities and a Novatec Solar group entity holding a minority share. A banking consortium of Commerzbank, BayernLB and Rabobank is providing debt funding to the project based on an ECA (Export Credit Agency) covered non-recourse project finance structure.

In August 2010, Novatec Solar has signed a contract for the turnkey delivery of a 9.3MW_{th} solar field in New South Wales, Australia. The solar field will be integrated into the existing Liddell coal fired power plant. Construction commenced in January 2011 and is expected to be completed in February 2012.

Further detail about Novatec Solar´s projects is presented in the following paragraphs.

6.1 PUERTO ERRADO 1 – 1.4 MW_E – SPAIN

The solar power station Puerto Errado 1 (PE 1) has an electrical output of 1.4 MW and is based on the linear Fresnel collector technology. The generated electricity has been fed into the local network since March 2009. The modular system NOVA-1 allows a scaling of solar fields from one to several hundred MW.

Key data on the solar power station PE 1	
Manufacturer	**Novatec Solar**
Product name	NOVA-1
Model	2 rows of linear Fresnel collectors, conventional steam turbine equipment and generator
Solar field length	806.40 m
Net aperture area	18,489.60 m²
Operating temperature	Up to 270 °C
Operating pressure	Up to 55 bar
Peak thermal output	9.3 MW_{th}
Peak electrical output	1.4 MW_{el}
Planned current output	2000 MWh/year


CERTIFICADO
Certificado de conformidad
CE 0036

6.2 PE 2 - WORLD'S FIRST UTILITY-SCALE SOLAR THERMAL POWER PLANT

The construction of the solar large-scale power plant Puerto Errado 2 (PE 2), started in the second quarter of 2010 and covers an area of 650,000 square metre with a total of 28 rows of mirrors. The plant will have an output of 30 MW and produce around 50 million kilowatt hours of electricity per year. This corresponds to the consumption of around 12,000 households.

Key data on the solar power station PE 2	
Manufacturer	**Novatec Solar**
Product name	NOVA-1
Model	28 rows of linear Fresnel collectors, conventional steam turbine equipment and generator
Solar field length	940.8 m
Net aperture area	302,000 m²
Operating temperature	270 °C
Operating pressure	55 bar
Peak thermal output	150 MW_{th}
Peak electrical output	30 MW_{el}
Planned current output	49 GWh/year

6.3 LIDDELL

Novatec Solar has been awarded the contract to build a new 9MW$_{th}$ solar field at Liddell, Australia, which will complement the existing plant, a world first integration of solar thermal technology with a traditional coal fired power station.

Construction of the 18,000 square metre solar field – the size of almost three football fields – is expected to commence in early 2011 and be completed in 2012.

Key data on the solar field Liddell	
Manufacturer	**Novatec Solar**
Owner	Macquarie Generation
Product name	NOVA-1
Model	4 rows of linear Fresnel collectors, solar augmentation of a coal fired power station
Solar field length	403,2 m
Net aperture area	18,489.60 m²
Operating temperature	270°C
Operating pressure	55 bar
Peak thermal output	9.3 MW$_{th}$
Thermal Output per year	13,550 MW$_{th}$

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